Edge Computing inInternet of Things (IoT)

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Abstract – Edge has become a growing trend in recent years. Bringing computing and analytics remarkably close to the data where it originated is the leading cause of edge computing. As the data is growing day by day, there arises the bottleneck in computation and network layers. Due to the enormous growth of Internet of Things (IoT) devices with its recent applications, the need for real-time computation has readily driven edge computing. Today data processing is an excellent paradigm for real-time data. In the integration of various IoT devices to solve the computing perplexities, created the emergence of the Edge computing. This paper clarifies concepts and contributions of edge computing associated with IoT devices. The proposed work produces a thumbnail survey on edge computing and its performance management towards IoT devices. The characteristics and architecture of Edge computing over IoT devices are furnished. The state-of-the-art on edge computing applications in the real-time scenario is discussed in this article. The proposed work explores the key benefits of Edge computing towards IoT devices, along with the comparative principles of edge computing over the Cloud, are represented. The existing challenges of edge computing are also discussed in this work.

Index Terms – Edge Computing, IoT devices, Data Processing, Performance Computing.

1. INTRODUCTION

Edge computing fetches memory and computes better than traditional data centre by bringing them significantly closer to the location whenever they are needed frequently in the form of local devices or any physical units across different areas. It is a disclosed platform integrating network, computation, storage, and other application entities on its edge of the network which is physically close to the data [1]. As the number of smart devices increases, day by day, the consumption of power in data centres also increases rapidly. In this case, the cloud cannot improve computing efficiency [2] to meet the increasing demand for the source of power. Cloud computing has a strategic form of data centres in its hand [3]. Of course, with substantial resource capacities with itself. As cloud servers handle more user applications, the cloud faces significant challenges to meet the energy consumption demand in the data centre. Now, improving the efficiency of energy consumption is existing research going on [4]. But the need for various tactile internet applications that include augmented reality and virtual reality, the demand for bandwidth dragged the enterprises towards the edge, and it became essential to have the servers very close to the edge for proper response. This response made edge computing come

into existence, focusing the distribution of infrastructure towards the edge devices and edge nodes [5, 6].

Next coming to the Internet of Things (IoT) applications, the cloud computing architecture faces severe problems. Mobile devices that are interconnected with cloud servers are placed at a certain distance, trying to obtain better services that increase the load on Radio Access Network (RANs), which results in very high latency [7]. IoT is drawing attention towards the digital transformation as the end-user demands are increasing [8]. Cisco reported that more devices similar to 50 billion are connected to IoT [9].The new challenges faced by IoT, including latency, constraint in capacity, resources, devices, uninterrupted connectivity and reliability, which cannot be promised by rationalized cloud computing[10]. IoT generates a massive quantity of data and exchanges those data relevant to real-world objects [11]. These IoT devices require a large scale of the network, heterogeneity in-network level and devices, considerable number of operating system events and applications. These features are a challenging task for real-time data, and it becomes very tough to be implemented by IoT and cloud environment [12]. Sending every data to the cloud needs high bandwidth which is not affordable with cloud framework. Recent research is investigating that only edge nodes can support these IoT devices and its requirements [13]. The proposed work discussed the concepts of edge devices in terms of architecture, potentialities, benefits, state-of-the-art on real-time applications, use cases, complementary concepts over cloud, challenges, and future directions. The different aspects of edge services depicted in Figure 1.
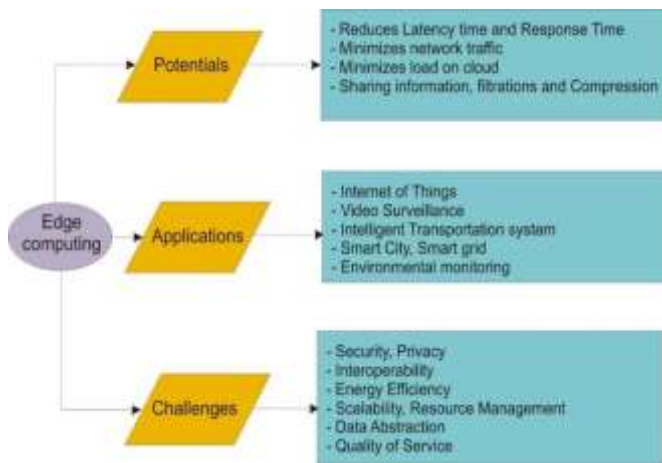

Figure 1 Edge Computing Progress in Different Aspects

2. LITERATURE SURVEY ON EDGE COMPUTING AND IOT

This section presents a comprehensive survey on the edge computing applications and potentialities embedded with IoT devices in diverse areas. The section also discusses edge

computing technologies solving many real-time issues with IoT devices.

Shufen Wange [14] discusses on development of smart homes using IoT devices. These IoT devices monitor the internal status of the home, regulates the home environment providing home safety and proper security. As everything cannot be uploaded in the cloud especially some video data, edge computing monopolized for processing home data through the gateway reducing the overflow of household data, prevent the leakage of data improving the privacy of the edge node.

M. Chen et al. [15] devised Edge and cognitive computing (ECC) that endows smart healthcare systems when the patients are in an emergency. The edge devices assigned according to the patient's health status. On assigned edge devices that process robustly with low latency, cognitive computation is carried out. The cognitive data engine collects the patient's data, and the cognitive resource engine collects the information relevant to edge, Cloud, and other network resources. The data is sent to these allocated resources according to the risk level and requirement of the patient.

Zhang et al. [16] proposed video analysis in edge computing. This video analysis is named as Edge video Analysis for Public Safety framework (EVAPS). With this edge computing framework, the video analysis workload is distributed optimally on both the edge nodes and the cloud Centre. The edge node prevents unnecessary data transmissions to the cloud.

L.U. Khan et al. [17] Proposed a smart city scenario using edge computing. In this system, the data is taken from the environment. Vehicles run applications and transmit data to the edge computing servers via roadside units (RSU) for further analysis and processing. The RSUs and edge servers are interrelated and finally connected to the cloud. For seamless connectivity and security, RSUs are deployed. The main objective of the proposed work is to reduce the cost of network deployment, fulfilling the quality of service.

B. R. Stojkoska and K. Trivodaliev [18] proposed an IoT and edge computing based smart home with a three-tier framework. The unit comprises smart homes tier, nano grid tier and microgrid tier. The first tier consists of a household item that enables wireless communication. The data is collected at the sink where it is locally processed and stored. In the second grid, sinks of smart home communicate with one another. This communication is enabled through mesh, cluster, or star. Sinks of various smart homes interact via IoT gateways enabled by the edge computing for reliable computation.

Richard Olaniyan et al. [19] defines the Opportunistic Edge computing (OEC) paradigm. It also furnishes the management framework to construct, organize and monitor the infrastructure of the scalable edge that also involves the

stakeholders. OEC utilizes the broker to launch pools of resources with the contributions of the end-user at the edge. Thus, OEC pools are used to bring the cloud nearby for a predefined duration. The author also compares the OEC model with that of the existing models. The experimental results depict the merits and demerits of OEC over cloud computing and fog computing. The paper also summarizes the resource management factors in OEC environments.

Yunkon Kim and Eui-Nam Huh [20] explores data caching concepts in edge computing. The state-of-the-art relays on machine learning, reactive and proactive caching. A lightweight caching algorithm, namely EDCrammer (Efficient Data Crammer), is implemented to manage computing resources. This algorithm uses an enhanced PID (Proportional Integral-Differential) controller for data streaming. EDCrammer helps in streaming data traffic, reduce the uplink load in the cloud by providing high-quality video services. This model cache data efficiently, and the caching rate is controlled amidst the cloud and the edge nodes. The algorithm produces a hit ratio of about 96% with a cache capacity of around 1.5MB. Thus, with the edge node, the user can receive better Quality of Service (QoS) by decreasing the load congestion on the data centre.

Y. Liu et al. [21] explored the computation offloading using edge computing. The main objective is to provide a better quality of service. The system framed a novel mechanism consisting of some set of interactions carried over amidst the cloud and local edge for the Stackelberg game. In this game, cloud server operator (CSO) serves as a leader that produces payments to end-server owners (ESOs), and this ESO is considered as a follower determining the computation offload for CSO. This model promises efficient computation offloading and extends its cooperation among ESOs.

J. Yang et al. [22] proposed a new model of smart IoT toys. The author deployed a new prototype for a data exchange accounting system based on edge computing. This prototype was designed with Hyper ledger Fabric-based blockchain system. Exchange and payments of data are made amidst demanders and suppliers through blockchain consortium. Smart contracts are deployed for validating the data exchange records and billing between the peers. The proposed system provides secure and reliable interactions between smart toys and IoT devices. This edge computing-based data exchange (EDEC) comprises five phases, namely registration, the release of data products, order generation, the transmission of data, accounting details and finally payment. The transactions are all recorded and stored on edge computing.

Z. Zhao et al. [23] deployed a three-step implementation approach to reduce the number of edge servers for improving the throughput between Edge nodes and IoT devices. The proposed model consists of three concepts such as discretization, utility metric and deployment algorithm. In the

first phase, the network is divided into small sections where the candidate node is determined. In the next phase, the utility metric evaluates the performance of every candidate node by validating the link quality and correlation. To achieve maximum throughput, the best node is deployed in the network. The proposed work describes certain concepts of edge computing and provides at most contributions in terms of real time applications and use cases in the IoT environment.

3. CONCEPTS OF EDGE COMPUTING

The smartness of Edge computing is that edge devices collect and share data without transporting to another end of the server. It brings the data close to the point of interaction. The concept of edge computing is stated as a computing mode that executes at the edge of the network. The cloud server is considered as downlink data, and IoT is justified as uplink data and edge to edge computing is deliberated as arbitrary computing [24-26].

Figure 2 Concepts of Edge Computing Framework

Edge computing can store and processing data significantly faster when compared to other devices. It is implemented for real-time applications. In edge computing, algorithms run on an edge server, or it increases the capacity of the smartphones by running algorithms via smartphones. The storage resources include cloudlets, data centre and fog nodes. And it operates at the edge of the network devices that remain nearing to the sensors or mobile devices [27]. The main objective of edge is to transmit the network of the cloud, storage, resources to the respective network edges providing brilliant services at the edge of the network devices to meet the emergency needs of the industries and factories. The edge computing is designed to meet the requirements of low latency with high bandwidth on the network edge. Now, edge computing is considered for many research purposes [28- 32]. The proposed work discusses the architecture, potentialities, benefits, use cases, state-of-the-art applications, and challenges of edge computing in IoT devices shown in the above Figure 2.

3.1. Edge Computing Architecture

Edge computing brings the resources of computation, storage, and networking significantly closer to the devices, users, and applications. It is viewed as one of the significant technologies associated with the Internet of Things and artificial intelligence in the next generation of networks [33]. It enables the data to travel at remarkably high speed without transferring data to the cloud or data centre. Edge computing is multilayered distributed architectures that balance the workload amidst edge layer, edge cloud, edge network and enterprise layer. Edge computing comprises three nodes: Device edge, Local edge, and Cloud. Figure 3 illustrates the overview of an edge architecture with the relevant components within each node. Industry solutions/Apps can be considered as duplicate components that exist both in the device edge and local edge. Specific workloads are integrated either with the device edge and local edge, and they can be dynamically migrated amid of the nodes either manually or automatically. Local edge node manages multi-cloud management, network services.

- The device edge is the place where the device is occupied. These devices include cameras, sensors and any physical devices gathering data and interact with edge data. Some applications such as AI models with deep learning, video analytics are managed on these edge devices.

- Local edge encloses both applications and the network. The applications of the device edge reside in this node. The non-runnable applications on the device edge are executed at local edge. Such as IoT processing. Some virtualized and containerized network layers will run on this local edge.

- Cloud is an environment where everything is brought together. It can either run at premises or as a public cloud. The applications that are not able to run in either of the nodes are handled by this cloud using orchestration layers.
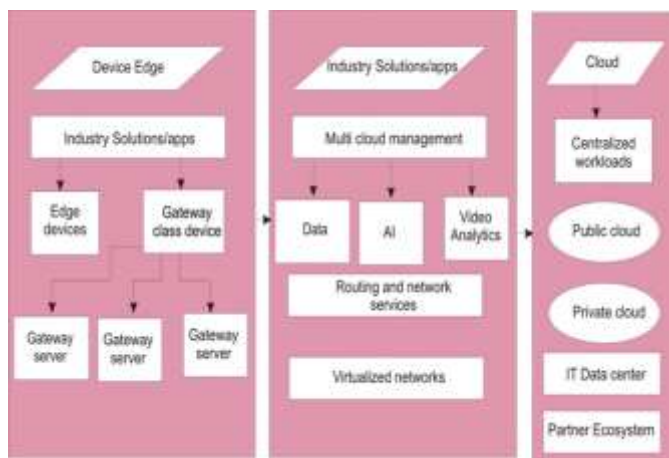

Figure 3 Edge Computing – An Overview

Edge computing can also be defined in terms of computing power and latency. It allows us to perform necessary computations with low latency with high computing-intensive calculations. Cloud, edge node, edge gateway and edge devices are the most essential layers in handling application and transmitting data at the edge devices. Figure 4 illustrates the layers of edge computing architecture [34].
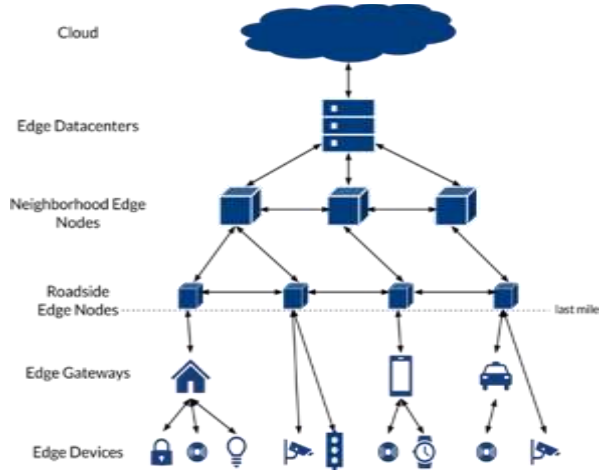

Figure 4 The Architecture of Edge Computing

The purpose of the cloud is to serve as long term storage and coordinates the resources in the case of irregular tasks. The edge node by default acts as downstream. These nodes possess high computation power, 2q manages the network traffic. On the other hand, edge gateway manages computations, and it serves as a platform for lower-level devices such as mobile phones, cars, and sensors. In contrast, edge devices are composed of limited resources that include single sensors and traffic lights.

3.2. Potentialities of Edge Computing

3.2.1. Edge Computing in Business

Nowadays, autonomous vehicles and medical sensors have become more common. Business and organization can extend their network services with the edge computing framework. Edge computing also identifies the machinery issues and fault tolerance level that provides safety for industrial manufacturers.

3.2.2. Edge Computing and IoT

Gadgets that are connected to the internetwork generate massive data which remains a challenge in managing and analyzing those collected data. This paradigm can be solved by edge computing by pushing the data from a centralized system to local edge centres that are close to the source. These data are analyzed in relative positions with low cost and better efficiency. The edge devices also solve low connectivity and transferring the cost of data. In the case of industrial IoT, edge

devices are self-regulated and dynamically respond to changes where the data are collected, analyzed, and implemented robustly.

3.2.3. 5G Networks

The accumulation of 5G networks increases bandwidth and transmits large volumes of cellular data. Integrating 5G networks with edge computing helps to keep more data on the edge node, and this reduces the latency issue by which data are transmitted via suboptimal bridges before they reach the concerned users.

3.2.4. Location Optimization

As per datacenters specification, it translates 80-90 ms for information from coast to coast in the United States. But with edge data centres, it takes just 5 – 10 milliseconds when the processing is close to the source. The data processing takes place in microseconds when the processing is done inside the edge device.

3.3. Benefits of Edge Computing in IoT

In Edge computing, data is processed at the location where it is generated. Every process is done instantaneously. Edge computing stores and analyzes the data at a remarkably high speed than the cloud. Another vital aspect of edge computing is data security whose primary need is to establish the integrity and security of data. Many types of research are focused on cloud computing [35], mobile cloud computing [36]. Thus, primary research is based on data security in edge computing which is done by migrating a secure data manner in a distributed environment with limited terminal resources. Some of the potential benefits of an edge are discussed in this paper. The key benefits are illustrated in Figure 5.
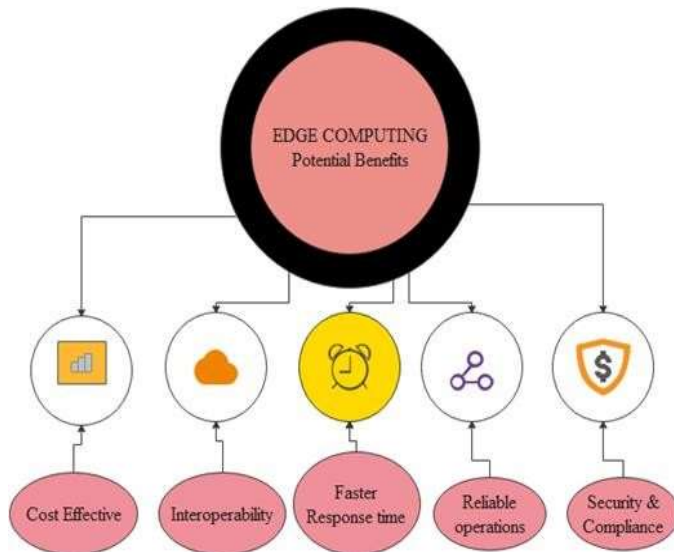

Figure 5 Key Benefits of Edge Computing

3.3.1. Cost-Effective

Using IoT devices are very costly because of their high bandwidth and storage capacity. With the use of edge computing for IoT devices reduces the bandwidth and data storage requirement. Edge computing also replaces the datacentres. Thus, edge computing significantly reduces the cost in IoT implementation. Infrastructure cost is also reduced by edge computing as only the relevant data alone are transmitted to the cloud, thus reducing the bandwidth.

3.3.2. Interoperability

Edge computing permits interoperability between the connected devices and legacy devices. It can convert communication protocols to suitable IoT connected devices.

3.3.3. Faster Response Time

Edge computing response at a remarkably high speed by reducing the latency, thereby increasing the network speed. It processes the data about the source at which the information is gathered, thus reducing the distance that it should travel. Therefore, the result is processed in microseconds. Edge computing is significantly faster in response to quality service.

3.3.4. Reliability

Edge computing provides uninterruptable services as it does not depend on an internet connection or any other servers. Data storage and processing are done locally using micro data centres. Thus, edge computing assures reliable connection for the IoT devices where it can be used in remote locations.

3.3.5. Security

Edge computing provides security as it is not dependent on network connections. Edge computing transmits only relevant information to the cloud. And it distributes processed work across different data centers and various devices. Thus, Distributed Denial of Service (DDoS) attack is prevented. As the data is stored and analyzed locally, it becomes easy to monitor the security team.

3.4. Edge Computing Vs. Cloud Computing

Edge computing is a group of local processing micro data centres and reduces the burden of a cloud. It is one regional office that takes over the computing tasks of the cloud instead of sending it to the data centre, which is an extremely far distance. Edge computing is contemplated as the complement of the cloud, and it does not mean to replace the cloud services [37]. They both are different that cannot be interchangeable. And these two technologies cannot be replaced where edge computing processes the time-sensitive data, but the cloud is not so. Nevertheless, edge computing is preferred in remote locations than the cloud, especially if there is limited or no connectivity to the central location. The

complementary aspects of edge and cloud are furnished in Table 1.

Complementary Aspects	Cloud Computing	Edge Computing
Data Processing	Data collected, analyzed, and processed at the other end. It is a centralized computing	Data collected, analyzed, and processed locally. It is a distributed based
Data Transfer	Any data processed is transferred to a cloud	No need for transferring. It reduces the workload on network and server
Data Management	Cloud dependent on the data centre	It handles with purpose-built systems and frees up the cloud computing
Minimum connectivity cost	Cloud uses a data centre to filter the sensitive data locally.	Filters the sensitive data at the source itself
Uninterrupted connection with Reliability	At cloud centres the connectivity is limited with some data loss.	Uses micro data centres data are stored locally and processed. Consume less bandwidth.

Table 1 Benefits of Edge Computing Vs. Cloud Computing

3.5. Edge Computing Use Cases

Edge computing ascertains better performance and security for IoT applications. IoT has already entered market in numerous ways. Now, enterprises and industries using IoT are in thirst of how edge computing applications can be converted into immense beneficial use cases. Some of the use cases of edge computing are described in this section.

3.5.1. Use Case in Video Surveillance

Edge computing nodes can recognize entities of interest which are then transmitted to the local edge. During fire accidents, edge computing can quickly determine whether a human is caught by fire as the cameras are located close to the event. And immediately it starts to transmit the video to the local edge. This is one of the significant use cases. With this surveillance cameras, a smart parking solution is also

possible. This system reduces the parking queues and finds the space very quickly by identifying the free parking slots. The concept of Image detection systems with surveillance cameras is utilized, which is done by convolution neural network (CNN) techniques. Edge computing also provides a promising solution in offering services to video streaming in smart cities [38]

3.5.2. Use Case in Connected Cars

In this system, data is collected from the various sensors and relevant information is sent to the base station, which is then transmitted to the edge node. In the case of video, it is transmitted to the data centre of the manufacturer. Thus, incorporating connected car data with the sensors improves traffic management such as traffic flow, traffic light controls and public transport. Human lives are saved by these connected cars. However, internal factors like airbag triggering, speed, brake, etc., provide immediate response to put the human lives out of danger.

3.5.3. Use Case in Monitoring Machines

Monitoring machines are possible with IoT sensors. It monitors the metrics of machines. These IoT sensors leverage edge computing stabilities and analyze the gathered data on the local edge. From the edge, it is transmitted to the cloud. Edge computing performs accurate measures and maintains the process before any interruptions occur. In connected parking meters, a resilient network is affixed for monitoring systems. This enables the data to transmit to the hub in the event of fault occurrence. As IoT sensors are embedded with the traffic lights and all smart devices in the environment, the edge computing monitors these data locally. The data are communicated and transmitted centrally only on fault reports.

3.5.4. Use Case in Healthcare

IoT devices play a significant role in providing solutions for the patient's health status. It receives real-time data of the patient from the cloud and offers robust analyzes in real-time. It provides a better solution when the patient is under critical condition. Edge computing is capable of processing and analyzing data and helps physicians to provide the correct diagnosis. Edge computing permits us to manage the connectivity, and data processing is done significantly closer where the data is gathered. For example, the Patient's data is collected through IoT devices where the patient is monitored and then transferred to an authenticated electronic health record (EHR) with proxy cards. Medical equipment may themselves assemble and process information during diagnosis and treatment.

3.5.5. Use Case in Train-Transport

A moving train is a fair use case when the train is connected to the internet. Nevertheless, edge computing launches the

network on the train. A wireless daisy chain is designed with two edge servers, thus providing coverage inside every carriage, which in turn linked to the next carriage. This acts as a standalone network without connecting to the cloud that is deployed at the local edge. Edge computing even favours when the passengers board the train with their luggage or vehicle. Passengers can have a smart ticket on their phone. When they reach the vehicle compartment, QR code or any barcode needs to be scanned so that the passenger can get a direct link to an IP camera to view the length of the train on the mobile.

3.6. State of the Art on Edge Computing Applications

In this section, the state- of- the- art on edge computing is set forth from the aspects of real-time applications. Edge computing has extended its applications in a variety of fields such as the gaming industry, retail, fleet management, health care, provides services for various sectors such as enterprises, industries. Few real-time scenarios are discussed in this section.

3.6.1. Autonomous Cars

Today, many industries are launching self-driving cars, as per the Gartner report, by 2025, it is said that autonomous vehicles may upload 1TB of sensor data to the cloud per month. In this context, Edge computing enables driverless cars or self-driving vehicles. This system enhances safety for both drivers and passengers alike. The autonomous vehicle is inbuilt with sensors capable of sensing the environment and road safety rules without human interaction. Accessing a car with a virtual car key brings a digital solution. This enables the drivers to utilize their smartphone or connected gadgets to access the car and start. The user can access vehicle information remotely in a secure manner where the physical key is not needed. Fleet control, e-autonomy and multimodal autonomy are other features important to this autonomous vehicle. The total care of the driver, the speed of the vehicle, power, health, and safety are included in fleet management. E-Mobility offers one hybrid vehicle with immediate communication facilities. On the other hand, multimodal mobility enables users to save time and efficiently travel from one place to another. Edge computing enables these vehicles to gather data and make brilliant decisions with high-speed data transmission and provides reliability at low latency.

3.6.2. Connected Ambulance

Generally, Diagnostic procedures are carried out only after the arrival at the hospital even during emergency. In this concern, connected ambulance plays a vital role in emergency services. Edge computing with its low latency, robust data processing capabilities and mobility at the edge node enables better treatment by paramedics onsite which is achieved by the following factors: 1. Live streaming of incoming patients' data and status from the sensors enabled through 5G.; 2. Patient

information and vital signs are analyzed at the edge for proper diagnosis.; 3. Edge renders augmented reality glasses for information display of patient medical history; 4. Remote ultrasounds that enable remote diagnostics by medical specialists.

3.6.3. On-Premises Patient Monitoring

Edge computing enables to process the data locally in the on-premises edge on the hospital site. The data privacy is maintained. The information is compiled from various sources within the hospital, and relevant information is extracted. Abnormal patient's behavior and status are monitored through Artificial intelligence(AI)by the edge and enable right-time notifications to the clinicians 360-degree view are made available for complete visibility of the patient dashboards to send corresponding data which is to be stored in a cloud securely. Thus, edge computing provides a significant resource for practitioners by reducing the cost per patient and increase productivity.

3.6.4. Edge Computing in Smart Cities

Autonomous vehicles are rising nowadays, and with the growing needs of the Internet of Things, smart cities will have the ability to respond instantaneously to the changing environment with the help of edge computing. Nowadays, IoT devices act as building blocks of a smart city. These devices are embedded in infrastructure of the city that helps to monitor performance of devices and periodical information about these assets. Edge computing transmits necessary technical information that includes traffic, flood, safety, and monitoring infrastructure. It relays more on-device computing for decision making in real-time by themselves instead of transmitting data to another node for processing. This mode of instantaneous response is an essential requirement for high bandwidth technologies like connected cars.

3.6.5. Augmented Reality (AR) Gadgets

There exists some wearable AR gadgets like head-mounted display (HMD) device. This device is applied recently in various fields like engineering, logistics medicine apart from defense applications. It consists of two tracking methods that include inside-out tracking and outside-in tracking. In the former tracking method, external sensor observes the users' head. Here in this type of tracking, camera is utilized as external sensor. In the second tracking method, sensor is computing from the observations. In this type sensor is mounted on the device.

3.7. Challenges of Edge Computing

Today more and more industries and IT sectors have started launching the edge computing devices due to its reliability and time management. But still, reliability is a huge challenge as edge computing fails to report low fidelity data under some

unpredictable circumstances due to the low level of battery [39]. Some communication protocol is proposed for IoT data which supports many sensor nodes and provides dynamic network connection [40]. Here some computing challenges of edge computing are discussed below: Table 2 furnishes some challenges of edge computing and provides some solutions to meet the challenges.

3.7.1. Computation with Hardware Restrictions

Edge computing is constrained in the technical aspect. It is challenging to fit more hardware on a data centre in a full scale.

3.7.2. Accessibility with Operation Issues

Edge computing faces some logical difficulties in deploying IT resources. It does not allow operator costs. On the other hand, the company cannot monitor every service and the edge locations. There also occurs operator limitations due to distance, device volume and other geographical issues.

3.7.3. Remote Paradigm

Skilled operators are needed to operate plug and play operations. In this scenario, edge computing should provide sophisticated facilities in terms of features such as data caching during interrupted connections. Data filtering, management of devices, fault tolerance and bandwidth usage.

3.7.4. Connection-Oriented Issues

There is a need for right technology providers to work with all latency issues, which plays a vital role in edge computing.

3.7.5. Air – Spaced Deployments

Edge computing faces challenges in managing remote and air-spaced devices. It is necessary to compute a constrained location without manual intervention.

3.7.6. Security

Another primary consideration is security. This means communication need to be secure from the data centre to the edge device. It should also ensure security both during stable and during transmission, especially sensitive data stored at the edge device.

Characteristics	Challenges	Addressing the Challenges
Scalability	Edge computing needs many monitors to understand the status and it needs servers and network devices. Finally, it becomes difficult to view	Intelligent software needs to be deployed to manage distributed heterogeneous environments. Thus, monitoring the status can be made ease without

	the status of the entire edge environment.	human interaction.
Performance	Monitoring the performance of the edge device in real-time in the consumer point of view from edge to cloud becomes difficult.	By providing technology to view end-to-end monitoring needs to be deployed, which helps in transactional performance from edge to cloud.
Controlling Operation	It sometimes slows down the activity in managing physical access, controlling IT equipment, managing the environment, tracking solving network issues when disconnected.	A low technology on motion detection that provides a holistic view to control edge environment when there is some lagging on power and network.
Security	Control access that too on all areas at all local edges seems difficult, which results in threat.	Solutions regarding unified view at all physical, network and access of data with automated responses need to be provided without client interruption.

Table 2 Edge Computing Challenges and Solutions
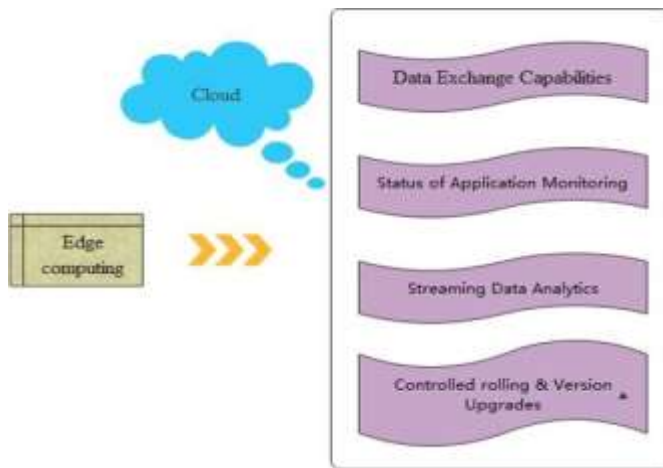
3.8. Edge Computing: Future Outlook

Figure 6 Future Directions of Edge Computing for IoT

Edge computing associated with 5G emerges with great opportunities in all industries. Its primary motivation is to bring the data storage and computation process around the data where it is generated. It enables proper data control, reduces the cost, brings deep insight, and provides continuous operations. By 2025, it is assumed that 75% of business data will be processed at the edge computing when compared today. Figure 6 depicts the capabilities of Edge computing in the future.

There arises a strong prediction for the next few years edge market will be headed very stubbornly. It has been estimated that the global revenue will reach $827.6 billion by 2025 for edge devices and edge networks. The main reason the edge is popularly growing is that it computes at local and edge locations than transmitting to the cloud. It filters the sensitive data during processing at the edge, and only the selected data is sent to the cloud. So, edge computing market will be in progress as the amount of data proliferates rapidly. Some future predictions of edge computing can be discussed here:

- The development of custom form factors will be driven for each use case from the processor level. A good example is that Hewlett Packard Enterprise (HPE) has invested 145 million US dollars for launching Pensando Systems to market a custom programmable processor.

- Many providers such as public mega cloud, telecommunication industries, software providers, and data centre providers are integrating with cloud programming services with edge computing infrastructure.

- The multi-vendor packaged solution is chosen by the companies. A survey by Forrester has revealed that the main motivation of the organization that needs from edge computing includes the capacity to handle the future Artificial Intelligence as edge computing minimizes network latency and affords fast responses.

4. DISCUSSIONS

In the technological perspective, edge computing is a providential framework enriching smart applications with expeditious computing and storage resources. Cloud is steadily deployed for smart devices with better computation and resource management. Due to its latency issues, computing and storage resources are transmitted and centralized node to the edge node, thereby reducing the burden of cloud computing. Thus, most of the services are pushed towards the edge, as edge computing ensures shorter response time with reliability. Edge computing has the potential to provide better intelligent services with a robust response in vehicle automation, video monitoring and other real-time applications. As every edge node is placed remarkably close to the source, data storage and processing take place in the edge computing node, thus minimizing the data transmission process. This edge computing plays a vital role in meeting the demands of IoT devices in real-time characteristics by improving production efficiency besides specific challenges.

5. CONCLUSION

This paper discusses some applications and potentialities of Edge Computing in IoT devices. To have a deep insight into edge computing, this article surveys some additional concepts of edge computing such as its architecture, state-of-the-art of edge computing applications in real-time scenarios. The paper enumerates some of the edge computing use cases in various domains. Nevertheless, the paper also provides some complementary aspects of edge computing with that of cloud computing. A comparison table has been provided concerning the benefits of edge overcloud. And the challenges of edge computing and addressing techniques have clearly been described in the proposed work. The paper offers systematic concepts of edge computing from the architecture to the challenges. The in-depth description includes data storage, latency and time-management as edge computing has become a research-oriented paradigm. The paper also sketches about the challenges of edge computing. Applications of Edge computing in IoT devices are furnished in this article. The paper investigates the outlook of edge computing. Though it faces some difficulty edge computing will be the future network in the real world which provides continuous development in the internet, AI, and also plays a vital role in human society and the geological environment.

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